

84th Combat Sustainment Wing

Hill AFB HVOF Implementation

HCAT
23 Jan 07

Ron Montgomery
Hill AFB

ron.montgomery@hill.af.mil

Clint Forrest & Craig Edwards
ES3, Inc. Aerospace Division

clint.forrest@es3inc.com

craig.edwards@es3inc.com



U.S. AIR FORCE

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 23 JAN 2007		2. REPORT TYPE		3. DATES COVERED 00-00-2007 to 00-00-2007	
4. TITLE AND SUBTITLE Hill AFB HVOF Implementation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) 84th Combat Sustainment Wing, Hill AFB, UT, 84056				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES 27th Replacement of Hard Chrome and Cadmium Plating Program Review Meeting, January 23-25, 2007, New Orleans, LA. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 29	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



HILL AFB HVOF PROGRAM



84TH COMBAT SUSTAINMENT WING

- Key Personnel in attendance today from Hill AFB
 - Ron Montgomery - HW Landing Gear Supervisor (not Chad's)
 - Chad Hogan - Landing Gear Lead Engineering PM
 - Brian Kemp- Process Engineer, HVOF Project
 - Clint Forrest - ES3 Landing Gear Engineer
 - Craig Edwards - ES3 Landing Gear Engineer
 - Richard Vander Straten- ES3 HVOF Program Manager
- Subcontractor support to Hill AFB/ES3
 - Metcut
 - Kamatics
 - Keeley Aerospace
 - HerouxDevtek



AGENDA



84TH COMBAT SUSTAINMENT WING

- HVOF Implementation
- Qualification Spec
- Diamond Grinding
- Duplex Coating
- Bearing Wear Test
- Questions



HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

■ HVOF implementation at Hill AFB

- Program to convert all line of sight chrome plate to HVOF WC-Co coatings on landing gear components
- Approximately 400 parts with an average of 4 surfaces per part = 1600 surfaces being converted to HVOF coatings

■ Combined Effort Between

- Hill AFB LG Engineering
- Hill AFB Process Engineering
- Hill AFB Production
- ES3 and Support Contractors



HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

■ HVOF Program Workflow

- Component selection
- Initiate System Safety Evaluation (SSE)
 - Unique to this program
 - Review part function
 - Review stress level
- Design and manufacture tools/fixtures
- Prototype Spraying
 - Adjustments made as needed
- Final Spray off and acceptance
- Initiate tech order changes
- Production spraying begins



HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

- **Field Service Evaluations (FSE) underway on B-1 MLG Axles**
 - Working on FSE for full ship-set on F-16





HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

- **Approximately 40 components converted at this time**
 - Approximately 300 components flying with HVOF coating
- **Aircraft currently flying with HVOF components**
 - A-10
 - B-1
 - B-52
 - C-5
 - C-130
 - F-15 C/D
 - F-16 HW
 - F-16 LW
 - KC-135
 - T-38



HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

Prioritized Parts Examples Cargo Bomber





HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

Prioritized Parts Examples Fighter Trainer





HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING

■ Hill AFB currently has two HVOF production booths

- Three additional booths on order
 - Installation June 07
 - Booth qualification begin summer 07
 - Bonds
 - Porosity
 - Hardness
 - Fatigue as required
 - Coating integrity as required
- One additional booth thereafter per year to 2012



ADDITIONAL HVOF WORK



84TH COMBAT SUSTAINMENT WING

- In addition to implementation program following projects being worked
 - Qualification specification
 - Diamond Grinding of 300M steel substrate
 - Duplex coating development
 - Bearing wear testing



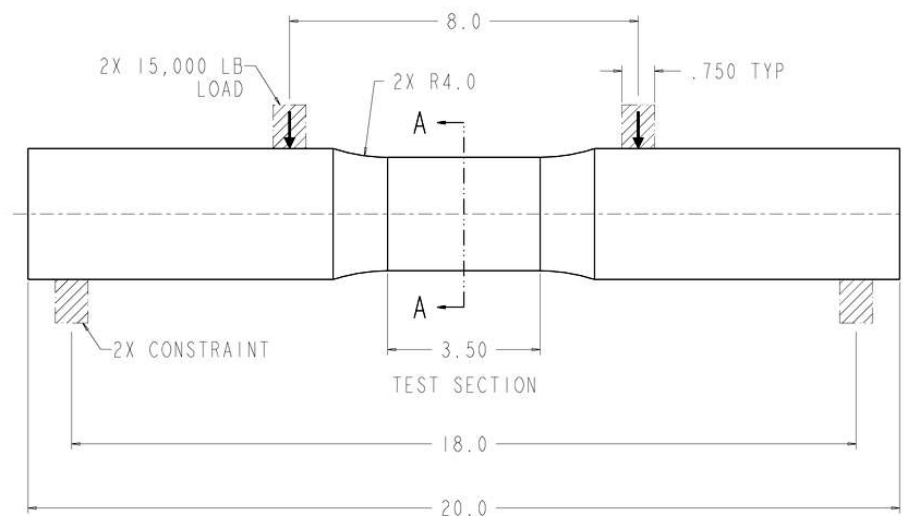
Qualification Specification



84TH COMBAT SUSTAINMENT WING

■ Qualification specification

- Establish a standard for USAF system qualification
 - Long term goal to qualify vendors for manufacture of spare parts
 - Criteria for HVOF vendors and suppliers to become qualified to spray Air Force LG components
- Air Force specification drawing
 - Process qualification
 - Powder qualification
 - ECD Spring 07





Diamond Grinding

84TH COMBAT SUSTAINMENT WING

■ Diamond grinding

- Investigating grinding 300M steel with same diamond wheel used on HVOF coatings
- Currently aluminum oxide wheels used for base metal and chrome plate, diamond wheels used for HVOF WC-Co coating
 - Using one type of wheel will prevent wheel change-out for grinding HVOF coatings
 - 180,220 and 320 grit wheel investigated

■ MIL-STD-866, Grinding of High Strength Steels used as baseline

- Typical process flow
 - Surface finish measurement
 - Conduct grind operation
 - Surface finish measurement
 - Conduct temper etch
 - Conduct Barkhausen Noise Inspection (BNI)



Diamond Grinding

84TH COMBAT SUSTAINMENT WING

Table 1: Grinding Specimens

Description	P/N	Material	Dimensions
Cylindrical	SK0425	300M	2"OD x 1.375"ID x 8"L
Stepped	SK0426	300M	2"OD x 1.375"ID x 4"L to 3"OD x 1.375"ID x 4"L (0.090"/0.125"transition radius)
Flat	SK0427	300M	3"W x 5"L x 0.125"/0.200NT





Diamond Grinding

84TH COMBAT SUSTAINMENT WING

- Initial results look very promising
- More work needs to be done
 - Contour grinding
- Draft copy of Air Force specification for Diamond Grinding of 300M steel is complete
 - Contour grinding not included



HVOF Duplex Coating

84TH COMBAT SUSTAINMENT WING

- **Duplex coating to be used to replace chrome/nickel repair use in landing gear**
 - Phase I showed promising results
 - Briefed in Spring 04 HCAT
 - On HCAT web page
 - Phase II to investigate a variety of powders for the build-up coat
 - Top coat to be WC-Co
 - Initial testing to include
 - Bond plugs
 - Porosity
 - Hardness
 - Qualification testing to include
 - Fatigue
 - Coating integrity
 - Corrosion
 - Stripping



Bearing Wear Testing

84TH COMBAT SUSTAINMENT WING

- **Testing to investigate interface wear of landing gear components using different finishing techniques**
 - HVOF and Chrome tested
 - Standard landing gear joint
 - Standard Al-Ni-Bronze bushing (AMS 4640)
 - Greased
 - Un-greased
 - KAron B
 - Greased
 - Un-greased
 - Shock Strut bearing
 - KAron VS
 - Lubricated with hydraulic fluid
 - Al-Ni-Bronze (AMS 4640)
 - Lubricated with hydraulic fluid



Bearing Wear Testing



84TH COMBAT SUSTAINMENT WING

■ Bearing Material

- AMS 4640 (15 ea 10KSI & 15 ea 30 KSI)
- Liner KAron B (30 KSI Journal Bearing 30 ea)
- Liner KAron VS (10 KSI Shock Strut Bearing 15 ea)

■ Pin Wear Coating

- Chrome (15 ea)
- HVOF (60 ea)

■ Lubrication

- MIL-PRF-81322 (Journal Bearing)
- Hydraulic Fluid

■ Finish Requirements

- Ra=8 max (Ground Pins)
- Ra=4 max, Rp=8 max, Rz=40 max, Tp=70-90% @ C=5% & .25Rz (Super-finished/800 Grit Pins)



Bearing Wear Testing



84TH COMBAT SUSTAINMENT WING

■ Finishing Techniques

- Chrome 220 Grit Aluminum-Oxide Ground (15 ea)
- HVOF 220 Grit Diamond Ground (15)
- HVOF 220 Grit Diamond Ground- Stone Super-finished (15)
- HVOF 220 Grit Diamond Ground- Belt Super-finished (15)
- HVOF 800 Grit Diamond Ground (15)

220 Grit Diamond Wheel



Stone Super-finisher



Belt Super-finisher



800 Grit Diamond Wheel

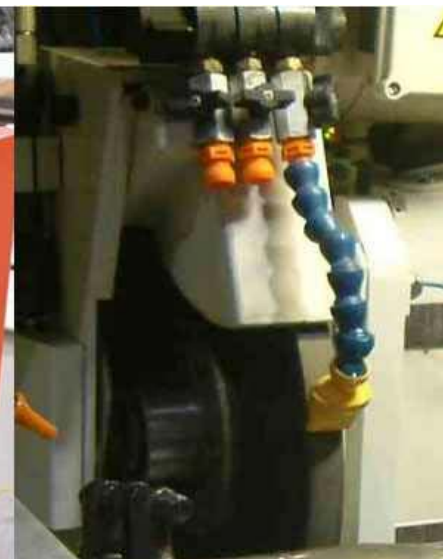


Photo Provided by Supfina

Photo Provided by Supfina



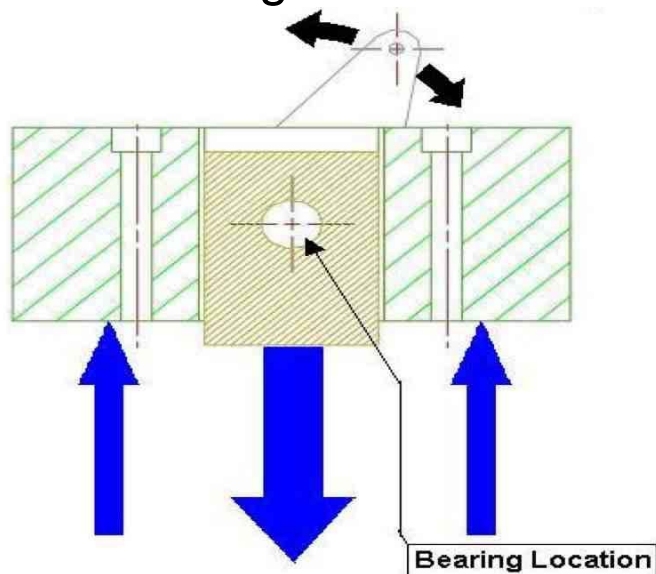
Test Set-Up and Loads



84TH COMBAT SUSTAINMENT WING

■ Journal Bearing Test

- Bearing Pressure 30 KSI
- Oscillatory Motion $\pm 25^\circ$
- 25,000 Cycles
- Bearing ID 1.000 inch
- Bearing Width 0.500 inch



Images Provided by Kamatics



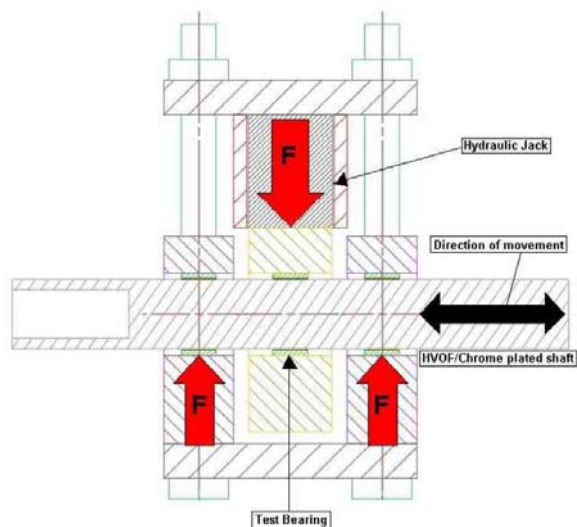
Test Set-Up and Loads



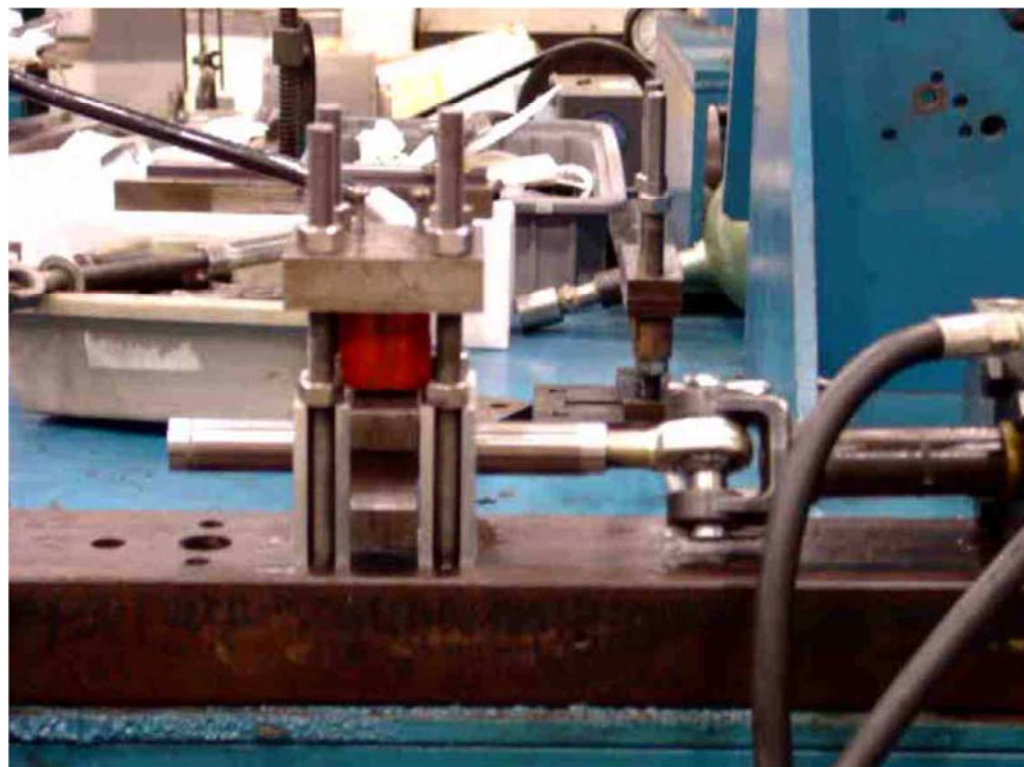
84TH COMBAT SUSTAINMENT WING

■ Shock Strut Bearing Test

- Bearing Pressure 10 KSI
- Linear Sliding Motion ± 1.0 inch @ 17 cycles/min
- 25,000 Cycles
- Bearing ID 1.000 inch
- Bearing Width 0.500 inch



Images Provided by Kamatics





Test Results



84TH COMBAT SUSTAINMENT WING

Journal Bearings AMS 4640- Lubricated

30 KSI Bearing Pressure Comparison Test Lubricated w/ Mil-PRF-81322 Grease, AMS4640 Bare					
Description	220 Grit Wheel Chrome Finish 1	220 Grit Wheel HVOF Finish 1	Super-Finish Stone HVOF Finish 2	Super-Finish Belt HVOF Finish 2	800 Grit Wheel HVOF Finish 2
Serial #	SAMPLE 1	KPD4536-37 / KPD4536-33	KPD4536-11	KPD4536-26	KPD4536-14
Bushing Material	AMS4640 - BARE	AMS4640 - BARE	AMS4640 - BARE	AMS4640 - BARE	AMS4640 - BARE
Ra (µin.) Before	6.8	3.3 / 3.6	3.6	2.1	2.5
Ra (µin.) After	172.6	68.2 / 13.1	103.8	128.5	7.0000
Shaft OD Before	0.9996	0.9998 / 1.0004	0.9998	0.9997	0.9999
Shaft OD After	1.0005 Build up	1.0005 BdUp / 1.0005 BdUp	1.0008 Build up	1.0050 Build up	1.0001 Build up
Bushing ID Before	1.0000	1.0000 / 1.0000	1.0000	1.0000	1.0001
Bushing ID After	1.0350	1.0100 / 1.0200	Destroyed	Destroyed	1.0100
Total Wear	0.035	0.0100 / 0.0200	0.0900	0.0200	0.0100
Total Cycles	8,200	10,200 / 10,200	5,256	8,000	10,200



Test Results



84TH COMBAT SUSTAINMENT WING

Journal Bearings KAron B- Lubricated

30 KSI Bearing Pressure Comparison Test Lubricated w/ Mil-PRF-81322 Grease, KAron B

Description	220 Grit Wheel Chrome Finish 1	220 Grit Wheel HVOF Finish 1	Super-Finish Stone HVOF Finish 2	Super-Finish Belt HVOF Finish 2	800 Grit Wheel HVOF Finish 2
Serial #	SAMPLE 2	KPD4536-01 / KPD4536-29	KPD4536-03	KPD4536-10	KPD4536-04
Bushing Material	KAron B	KAron B	KAron B	KAron B	KAron B
Ra (µin.) Before	5.6	2.5 / 3.4	3.5	2.8	2.9
Ra (µin.) After	4.5	3.0 / 3.1	2.7	2.7	2.5
Shaft OD Before	0.9997	1.0001 / 1.0002	0.9995	0.9998	0.9997
Shaft OD After	0.9997	1.0001 / 1.0002	0.9995	0.9998	0.9997
Bushing ID Before	1.0005	1.0000 / 1.0000	1.0005	1.0000	1.0005
Bushing ID After	1.0005	1.0010 / 1.0008	1.0005	1.0020	1.0015
Total Wear	0	0.0010 / 0.0008	0	0.0020	0.0010
Total Cycles	25,000	25,000 / 25,000	25,000	25,000	25,000



Test Results



84TH COMBAT SUSTAINMENT WING

Journal Bearings KAron B- Dry

30 KSI Bearing Pressure Comparison Test Dry					
Description	220 Grit Wheel Chrome Finish 1	220 Grit Wheel HVOF Finish 1	Super-Finish Stone HVOF Finish 2	Super-Finish Belt HVOF Finish 2	800 Grit Wheel HVOF Finish 2
Serial #	Sample 1 / Sample 4	KPD4536-06 / KPD4536-16	KPD4536-35	KPD4536-34	KPD4536-02 / KPD4536-39
Bushing Material	KAron B	KAron B	KAron B	KAron B	KAron B
Ra (µin.) Before	6.1 / 5.9	3.5 / 3.4	2.5	2	2.6 / 2.6
Ra (µin.) After	5.2 / 5.1	2.8 / 3.1	2.1	1.6	2.6 / 2.1
Shaft OD Before	0.9995 / 0.9995	1.0000 / 0.9998	0.9996	1.0000	1.0002 / 0.9997
Shaft OD After	0.9995 / 0.9995	1.0000 / 0.9998	0.9996	1.0000	1.0002 / 0.9997
Bushing ID Before	1.0000 / 1.0000	1.0000 / 1.0000	1.0000	1.0002	1.0000 / 1.0005
Bushing ID After	1.0005 / 1.0010	1.0007 / 1.0009	1.0000	1.0002	1.0010 / 1.0010
Total Wear	0.0005 / 0.0010	0.0007 / 0.0009	0	0	0.0010 / 0.0005
Total Cycles	25,000 / 25,000	25,000	25,000	25,000	25,000



Test Results



84TH COMBAT SUSTAINMENT WING

Shock Strut Bearings AMS 4640-Lubricated

10 KSI Bearing Pressure Comparison Test Lubricated , AMS4640

Description	220 Grit Wheel Chrome Finish 1	220 Grit Wheel HVOF Finish 1	Super-Finish Stone HVOF Finish 2	Super-Finish Belt HVOF Finish 2	800 Grit Wheel HVOF Finish 2
Serial #	SAMPLE 1	KPD4547-16	KPD4547-23	KPD4547-07	KPD4547-09
Bushing Material	AMS4640 - BARE	AMS4640 - BARE	AMS4640 - BARE	AMS4640 - BARE	AMS4640 - BARE
Ra (µin.) Before	5.7	2.8	3.5	2.3	2.4
Ra (µin.) After	10.7	22.3	4.6	37.2	5.1
Shaft OD Before	0.9997	0.9997	0.9995	0.9996	0.9995
Shaft OD After	0.9996	0.9996	0.9994	0.9996	0.9995
Bushing ID Before	1.0000	1.0000	1.0000	1.0000	1.0000
Bushing ID After	1.0020	1.0070	1.0010	1.0040	1.0030
Total Wear	0.0020	0.0070	0.0010	0.0040	0.0030
Total Cycles	25,000	25,000	25,000	25,000	25,000



Test Results



84TH COMBAT SUSTAINMENT WING

Shock Strut Bearings KAron VS- Lubricated

10 KSI Bearing Pressure Comparison Test Lubricated, KAron VS					
Description	220 Grit Wheel Chrome Finish 1	220 Grit Wheel HVOF Finish 1	Super-Finish Stone HVOF Finish 2	Super-Finish Belt HVOF Finish 2	800 Grit Wheel HVOF Finish 2
Serial #	SAMPLE 2	KPD4547-22	KPD4547-19	KPD4547-10	KPD4547-20
Bushing Material	KAron VS	KAron VS	KAron VS	KAron VS	KAron VS
Ra (µin.) Before	5.5	3.2	2.9	2.9	3.6
Ra (µin.) After	2.1	3.0	2.5	2.3	2.5
Shaft OD Before	0.9996	0.9998	0.9996	0.9995	1.0000
Shaft OD After	0.9996	0.9998	0.9996	0.9995	1.0000
Bushing ID Before	1.0000	1.0000	1.0000	1.0000	1.0000
Bushing ID After	1.0060	1.0040	1.0040	1.0030	1.0020
Total Wear	0.0060	0.0040	0.0040	0.0030	0.0020
Total Cycles	25,000	25,000	25,000	25,000	25,000



Conclusions



84TH COMBAT SUSTAINMENT WING

- **Lubricated AMS 4640 Journal Bearing Testing @ 30 KSI**
 - HVOF super-finished pins performed poorly
 - Super-finishing does not improve wear rate
 - AMS 4640 bearing compromised during test
 - Significant surface finish degradation
 - Pin size enlarged - material transfer
 - HVOF pins finished with 220 and 800 grit wheels performed well
 - Chrome pin finished with 220 grit wheel had higher wear
- **Lubricated KAron B Journal Bearing Testing @ 30 KSI**
 - Super-finishing HVOF does not appear to improve wear rate
 - Better wear properties than AMS 4640
 - Chrome and HVOF performance equivalent
- **Dry KAron B Journal Bearing Testing @ 30 KSI**
 - Super-finishing HVOF does improve wear rate
 - Best combination for high loaded Joint



Conclusions



84TH COMBAT SUSTAINMENT WING

- **Lubricated AMS 4640 Shock Strut Bearing Testing @ 10 KSI**
 - All process exhibited equivalent wear rates except 220 grit HVOF (nearly double)
 - Baseline chrome AMS 4640 bearing performed as well as any
 - 220 grit wheel Belt super-finish had significant surface degradation
- **Lubricated KAron VS Journal Bearing Testing @ 10 KSI**
 - Super-finishing does appear to improve wear rate
 - KAron VS similar wear properties to AMS 4640
 - Surface finish degradation less on KAron VS
- **All processes tested exhibited similar performance to the baseline**
- **Tests results once approved by USAF will be placed on HCAT web site**



HILL AFB HVOF PROGRAM



84TH COMBAT SUSTAINMENT WING

■ Questions??